Detection of Missed and Failed Breath-Holds During SBRT Active Breathing Control

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Background:

Stereotactic body radiation therapy (SBRT) requires motion management to ensure high dose is delivered to moving targets and away from normal tissue [1,2]. Active breathing control using voluntary breath-holds (BH), reduces respiratory and bowel motion [3,4]. Stand-alone BH systems such as SDX (Dyn'r Medical Systems Aix-en-Provence, France) that do not natively communicate with the treatment machines, require manual intervention to start and stop radiation delivery. Therefore, it is crucial to know if during treatment there were missed BHs (defined as a patient not reaching lung capacity) or failed BHs (defined as unexpected BH releases).

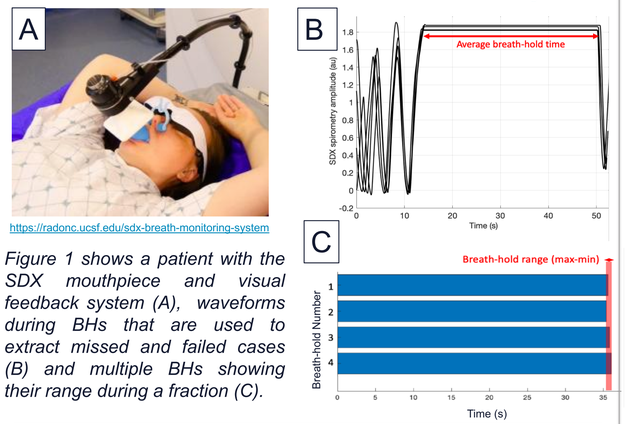
Purpose:

We propose developing an automated method that enables review and quantitative analysis of BH during treatment. The impact of this work is: (1) quality assurance checks of SDX treatments to identify fractions where manual beam on/off control was required, and (2) identification of patients that may benefit from closer monitoring or training for future treatments to improve breath control.

Methods:

An automated workflow was developed to analyze SDX BHs post-treatment using Python. For each fraction, multiple BH waveform was recorded and quantitative metrics were extracted to assess treatment, such as BH time range, number of missed holds (BHs shorter than 2 seconds), and number of failed holds (BHs longer than 2 seconds but shorter than mean BH minus 5 seconds) as shown in Fig. 1. Following each fraction delivery, a summary report is generated (see Fig. 2) and an automated email was sent alerting the clinical team for review.

Results - Automated BH Analysis



https://radonc.ucsf.edu/sdx-breath-monitoring-system

Figure 1 shows a patient with the SDX mouthpiece and visual feedback system (A), waveforms during BHs that are used to extract missed and failed cases (B) and multiple BHs showing their range during a fraction (C).

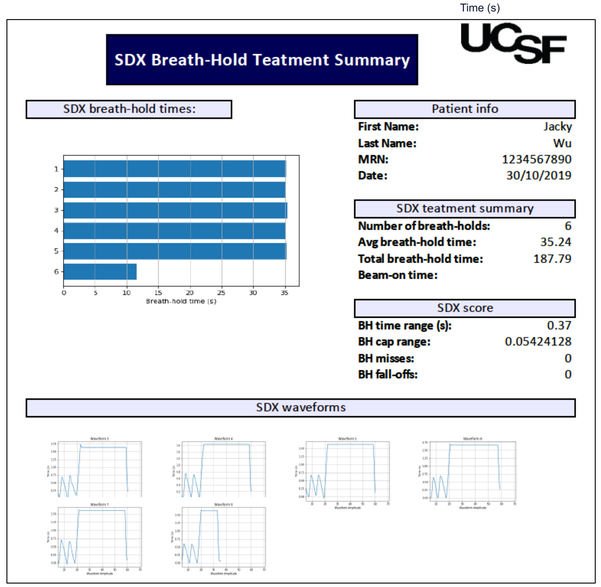


Figure 2 shows an example summary reports of a single SDX treatment fraction that did not have any BH misses or fall-offs. The range of BH times, average BH time and waveforms are used to evaluate treatment.

Results - Missed and Failed BHs

Errors (missed or failed BH) occurred at some point during treatment in 45.7% of patients, 55.0% of fractions and 8.9% of all BHs for all treatment sites.

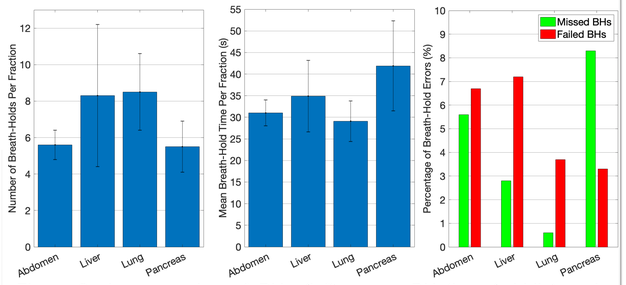


Figure 3 shows number of BHs (left), mean BH time (middle) and percent of missed and failed BHs (right) for each treatment site.

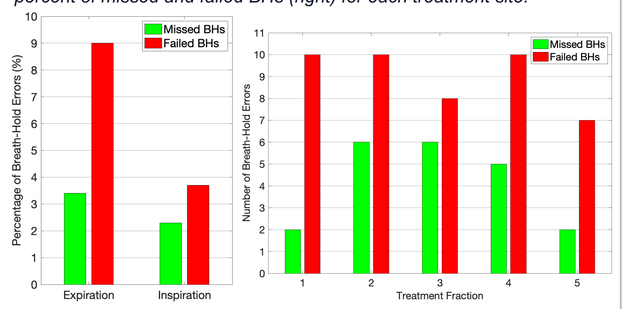


Figure 4 shows percentage of BH errors during expiration and inspiration holds (left) and number of errors that occurred at each treatment fraction.

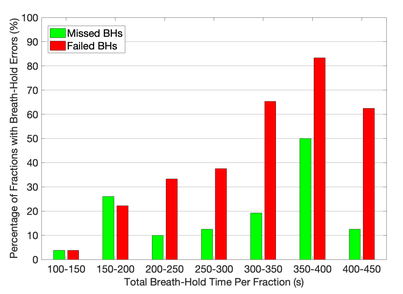


Figure 5 shows the percentage of fractions that had a BH error (missed or fail) as a function of total BH time per fraction. Missed BH seem to be independent of BH total time, whereas BH fails increase with longer total BH time.

Discussion:

A total of 1160 BH waveforms in 151 SBRT fractions (57 inspiration and 94 expiration) from 35 patients were analyzed. There were 4 abdomen treatments (17 fractions) with a mean (range) dose of 35.2Gy (33 – 37.5Gy), 22 liver treatments (94 fractions) at 43.5Gy (25 – 50Gy), 5 lung treatments (19 fractions) at 46Gy (40 – 50Gy) and 4 pancreas treatments (11 fractions) at 33Gy in 5 fractions. Failed BHs pose a greater concern than missed BHs because a delay in manual beam stop could lead to missed targets and toxicities. Treatments with expiration had a higher number of failed BH than inspiration. Also, failed BH were more likely to occur during fractions with longer total BH time.

Conclusion:

Evaluation of motion management techniques between fractions and post-treatment would further strengthen confidence of accurate dose delivery, especially for treatments with manual beam control. We have developed a tool that enables easy review and documentation of SDX treatment breath-holds that could be used to identify errors and improve patient treatment.

References:

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